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Time Budget of Activity in the Water Spider *Argyroneta aquatica* (Araneae: Argyronetidae) under Rearing Condition

Toshiya Masumoto[1), Tomoko Masumoto[2), Makoto Yoshida[3) and Yoshiaki Nishikawa[4)

桝元敏也・桝元智子・吉田　真・西川喜朗：飼育下における
ミズグモの活動の時間配分

Abstract The water spider *Argyroneta aquatica* (Argyronetidae) is the only spider that lives under water. We conducted observation on the time budget of daily activity and some life history characteristics of this spider under rearing condition. All adult males died until August, but adult females were alive until next year and produced three or four egg sacs throughout their life. Females protected her egg cases after oviposition. Juveniles were observed to get out of their egg sacs about 3 days after hatching, and dispersed by swimming, not by ballooning. Juveniles matured next Spring. The water spider seems to complete their life within a year. The activity of the spider was recorded with a video. Juveniles and adult females acted mostly at night, but they spent most of the time in the air dome. Consequently, the proportion of time spent for activity to the total observation time was less than a few percent. In contrast, the activity of adult male was observed frequently also in the daytime.

Introduction

The water spider *Argyroneta aquatica* is the only spider that can walk and swim under water, and is the only species belonging to the family Argyronetidae (Yaginuma 1977). The water spider is not able to respire in the water, unlike aquatic insects, because of the lack of gills. However, the water spider makes an air dome in the water and keep air in it, and feeding, copulation, and oviposition are conducted in the dome. When the water spider swims in the water, air is attached to the surface hairs of its abdomen with the surface tension (Foelix 1982). Molting, feeding, copulation, and egg production are conducted in the air dome (Bristowe 1959).

The water spider is thought to be a relic since gracious period (Yaginuma 1977). Katsura & Nishikawa (1981) pointed out that the deterioration of the habitat condition of the water spider makes their distribution limited in Japan recently. For the conservation of the population of the water spider, we should clarify population size and population structure in the field. To do this, we should know the difference of daily activity patterns among males, females and juveniles, because the activity pattern affects the estimation of the size and the structure of the field population. The aquatic life and the low oxygen consumption rate of the water spider (Stranzny & Perry 1984, Edgar

1) Center for Ecological Research, Kyoto University. 509–3 Otsuka, Kamitanakami-Hirano, Otsu, Shiga, 520–2113, JAPAN

2) 1–20–37, Sakurano-cho, Otsu, Shiga, 520–0026, JAPAN

3) Ritsumeikan University, 1916, Nozi-cho, Kusatsu, Shiga, 525–8577, JAPAN

4) Biological Laboratory, Otemon Gakuin University, 2–1–15, Nishi-Ai, Ibaraki, Osaka, 567–8502, JAPAN

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1971, Anderson 1970) may affect the activity pattern and make their activity different from other terrestrial spiders. However, there have been no reports on these subjects. Furthermore, the life history characteristics, such as the longevity, would also affect the estimation of population size and structure. However, there are few researches on the longevity of the water spider (Yoshida *et al.* 1994).

In this paper, we report the quantitative data about the time budget of activity under rearing condition and some life history characteristics of the water spider.

Materials and Methods

Collecting and rearing the spider

The water spiders were collected at Mizoro pond in Kyoto city, Japan on March 20 and May 1, 1996. Two adult males (m001, m002), two adult females (f011, f014), three subadult males (m003, m004, m005) and one subadult females (f001)were captured and reared in the plastic or glass container (18cm in length, 35cm in width, and 20 cm in height) under the room temperature. *Aselli* (Crustacea) were offered as prey. As adult spiders were reared separately, they did not copulate under rearing condition. Thus adult females were previously copulated before collection, because eggs of two adult females hatched as described below. Adult males, m004 and m005, molted and became adult on May 18 and May 12 respectively.

Some life history events, such as oviposition and dispersion, were recorded. When the juveniles hatched from egg sacs, we recorded the behavior of dispersion.

Recording the activity

We recorded the time budget of the activity of the spider with a video recorder and a camera for infrared light. The room light was off in between 23 : 00 and 5 : 00, though this dark period was shorter than natural dark period. Water temperature was similar to the room temperature, from 23°C to 28°C. Behaviors of the spider were categorized as "act" and "rest". The category "act" includes walking on the air dome, swimming, and the air transport from the water surface to the air dome.

During the video recording, prey were not supplied to spiders, so we could not recorded hunting and feeding behavior. For the analysis of the activity in a time of a day, one day was divided into four periods; from 23 : 00 to 5 : 00, from 5 : 00 to 11 : 00, from 11 : 00 to 17 : 00, and from 17 : 00 to 23 : 00.

Results

Life history under rearing condition

One subadult female f001 died three weeks after the start of rearing. Oviposition sequences of two adult females, f011 and f014, were shown in Fig. 1. Adult female f011 produced the first egg sac on June 5, and juveniles got out of the sac on June 26. And f011 produced the second egg sac on July 7, and juveniles got out of the sac on July 23. Furthermore, f011 produced the third egg sac on September 10, but no juveniles hatched. F011 overwinterd and produced the forth egg sac on 30 April, but no juvenile hatched. The female f011 died on 4 June, and it survived 367 days from the captured date of May 1. Adult female f014 produced the first egg sac on June 5, and juveniles got out of the sac on June 26, and produced the second egg sac on July 7, but no juveniles hatched.

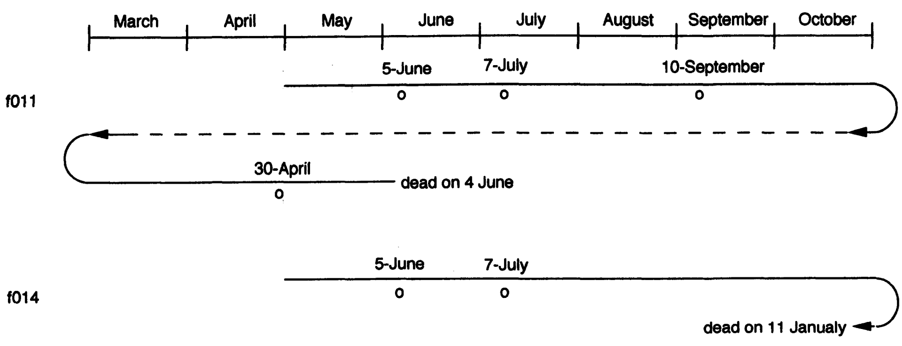

Fig. 1. Sequence of oviposition of two females of *Argyroneta aquatica*. "o" indicates the date of oviposition.

This female died on January 11. All males died until August. Though we could not count the number of juveniles exactly, we found that 20–30 newly hatched juveniles from one egg sac.

We observed that juveniles hatched even from the outside of the egg case. Juveniles were observed to get out of their egg sacs about 3 days after they hatched, and became exclusive to other individuals, and started to cannibalize each other. Juveniles moved and dispersed only by swimming, but we did not detect ballooning behavior. Among juveniles, one female became adult in December and one male became adult in May.

Time budget of activity

A total recording time amounted to 508 hr 17 min, and the recording time for each individual spider is shown in Table 1. And the sequences of the time budget of sub-adult and adult males were shown in Fig. 2. Sub-adults, two females and one male (Record No.5) acted mainly during dark periods, and showed low activity during light periods. However, adult males (Record No 6,7) showed high activity during both dark and light periods. Most of the activity of adult males was swimming.

The number of air transport to the air dome was also described in Table 1 and Fig. 2. For adult males, we could not discriminate between air transport and swimming near water surface, so the number of air transport of adult males was not shown. The water spiders had a tendency to concentrate the air transport in the dark period.

Discussion

Life history

In our rearing condition, females of *A. aquatica* produced three or four egg sacs throughout their life, and one female survived until the next June. The long oviposition period from April to August would make a large size variation of juveniles. Though the water spider has been suggested to have a semivoltine life cycle, because of the large size variation in spring (Yoshida *et al.* 1994), our results indicate univoltine life cycle.

Considering the conservation of the population of the water spider in Japan, we must know the life history characteristics that affect the population parameters. From the results of the two females reared, a female of *A. aquatica* produces at least 60 eggs

Table 1. Results of recording time (month/date, hr: min) and the number of air transport to air dome observed.

Record No.	Individual	Stage and sex	Start of recording	End of recording	Total recording time	No. of air transport	No. of air transport/hr
1	f001	subadult female	3/25, 21:26	3/28, 14:30	65:04	25	1.46
2	f001	subadult female	4/2, 23:30	4/4, 14:09	38:39	32	2.18
3	m003	subadult male	4/8, 9:01	4/14, 23:30	110:20	68	4.74
4	m001	adult male	5/7, 0:18	5/8, 5:37	29:19	—	—
5	m001	adult male	6/5, 12:00	6/7, 0:20	31:09	—	—
6	m004	adult male	6/25, 0:00	6/26, 13:10	37:10	—	—
7	m005	adult male	6/25, 0:00	6/26, 13:10	37:10	—	—
8	f011	adult female	5/12, 23:40	5/16, 8:05	79:43	13	1.68
9	f014	adult female	5/12, 23:40	5/16, 8:05	79:43	22	2.85

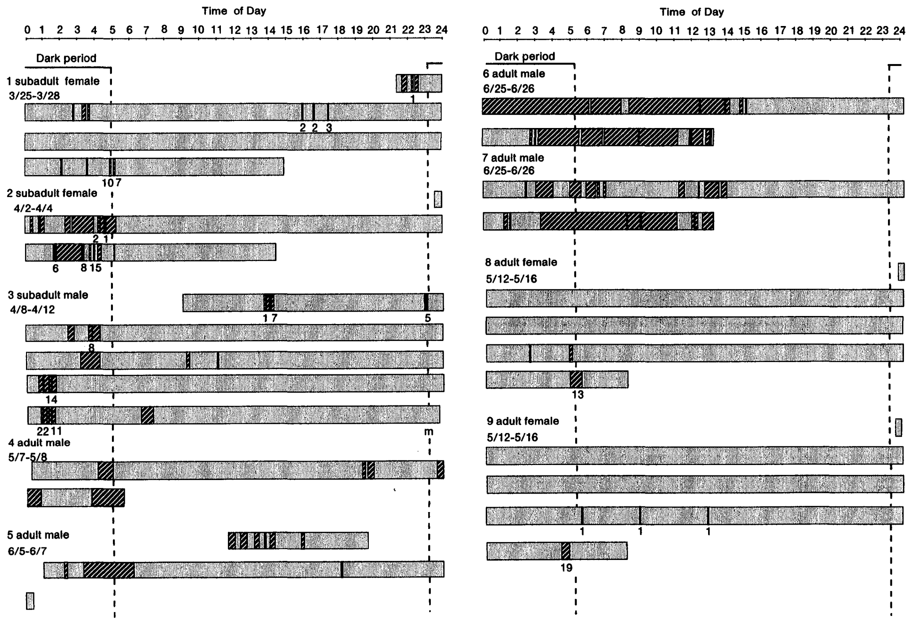

Fig. 2. Sequence of daily activity of *Arygoroneta aquatica*. Numbers under the bars indicate the number of air transfer from water surface to air dome.
m: molting, ▒: resting, ▨: acting, such as swimming, walking, air transfer to air dome.

through her life, if she produces at least three egg sacs, each of which contains 20 eggs.

We observed that juveniles dispersed by swimming, not by ballooning. The water spider has a low tolerance to desiccation because the rate of water loss is 2.42% of the body weight per hour, while the rate of water loss is 0.02% in the *Theraphosid* spider (Stewart & Martin 1982, Cloudsley-Thompson & Constaninou 1983, Pultz 1987). Low tolerance to desiccation would favor dispersion by swimming, not by the dispersion by ballooning.

Time budget of activity

Spiders have been reported to have a daily activity pattern (Cloudsley-Thompson 1978): some spiders, such as *Araneus* spiders, are active only at night, while others, such as jumping spiders, are active only in the daytime. In this study, the proportion of time spent for activity to the total time of adult females was shorter than that of the others. This low activity would be affected by the low oxygen consumption rate. Because the oxygen consumption in the water spider is approximately half the minimum oxygen consumption rate of *Tegenaria* (Stranzny & Perry 1984), one-third the oxygen consumption rate of the wolf spider *Pardosa lugubris* (Edgar 1971), and similar to the low values measured for *Theraphosid* spiders (Anderson 1970). The water spider seems to have adapted to the environment with low oxygen concentration (Masumoto *et al.* 1998). The low activity especially in the daytime in juveniles and adult females may reduce the

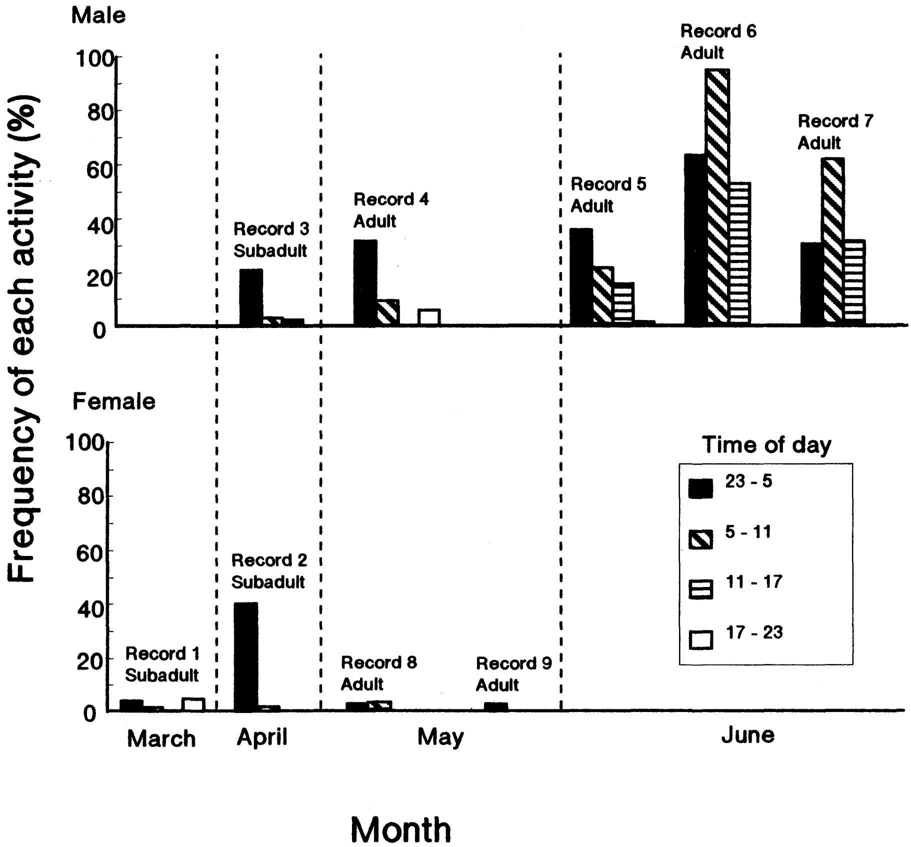

Fig. 3. Daily activity frequency of *Argyroneta aquatica*. One day was divided into four periods; from 23 : 00 to 5 : 00, from 5 : 00 to 11 : 00, from 11 : 00 to 17 : 00, and from 17 : 00 to 23 : 00.

risk of predation by day-active predators.

However, the activity pattern of adult males in June is different from that of the others. The high activities of adult males during the daytime may be related to mating behavior. As males of the water spider show high activity during the daytime, some potential predators, such as fish, would easily detect them. Katsura and Nishikawa (1981) suggested that water spider seemed to be able to live where no fish was observed, because fishes possibly acted as an intense predator to the water spider. Enemy free habitat may allow adult males to search for mates actively even during the daytime. Further research in the interaction between the water spider and their potential predators are needed.

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摘　要

ミズグモ *Argyroneta aquatica* は水中で生活する唯一のクモである．我々は飼育しているミズグモの一日の行動時間配分と生活史に関する観察を行った．雄は 8 月中に死亡したが，雌は翌年まで生存し 3，4 個の卵嚢を生涯に産卵した．ミズグモの雌は産卵後，卵嚢を保護した．幼体は孵化後約 3 日後に卵嚢から出てバルーニングではなく，泳いで分散した．幼体は翌年の春には成体になった．ミズグモは年 1 化で生活史を完結するとみられる．クモの活動はビデオに記録し解析を行った．幼体と成体雌の活動はほとんど夜間に行われた．また，ドーム内でじっとしている時間が長く，活動している時間は総時間の数パーセント以下であった．一方，成体雄は日中も活発に活動した．

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